

SHIPBOARD MEASUREMENTS IN THE TROPICAL WESTERN PACIFIC PROGRESS REPORT

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Our ARM research program is a combination of instrument/technique development, field measurements, and specialized modeling. ARM has provided support for three major field programs: the Atlantic Stratocumulus Transition Experiment (ASTEX) held in the N. Atlantic in 1992; the Pilot Radiation Observation Experiment (PROBE) held at Kavieng, PNG, in 1992-93; and the Combined Sensor Program (CSP) held in the equatorial Pacific in 1996. A follow-on experiment (Nauru99) was completed in June-July 1999 (see www.etl.noaa.gov/nauru99). The majority of the effort in FY00 involved analysis of data from Nauru99. The modeling effort is primarily in the realm of large eddy simulations and cloud resolving models that are intended to bridge the gap between observations and climate models. A complete reference list (76 refereed papers, 109 conference proceedings, and 6 technical reports) has been prepared and is appended as a separate file; some 7 refereed papers and 15 conference papers were added in the last year.

Our major accomplishments in the last year are:

- *Developed and deployed a dual IR/Microwave sea-surface scanning radiometer system.
- *Developed a direct- and improved the tip-calibration method for the ARM MWR.
- *Verified a new combined MWR/MMCR cloud liquid water profile retrieval method.
- *Developed a lidar-based method to retrieve microphysical properties of subcloud aerosols.
- *Completed the Nauru99 field program.
- *Obtained datasets for future SCM studies of the TWP at 200-km and 50-km scales.
- *Obtained a variety of data for future characterization of island effects at Nauru.
- *Uncovered some data quality problems with the NOAA TAO buoys in the vicinity of Nauru

1. System and Technique Development

1.1 Radiometers

Much of the 99 activities were spent on design of the scanning infrared radiometer that was deployed on the R/V Ron Brown during Nauru99. A scanning system was constructed that was close in design and performance to our scanning 5-mm radiometer. A trolley was designed and constructed to allow the instruments to be situated about 5 m from the seatainer and then to scan in a vertical plane over the water. Analysis of data from the Nauru99 experiment showed excellent performance for the scanning 5-mm radiometer; both vertical profiles of air temperature and time series of sea-temperature differences were derived. These derived products agreed well with *in situ* measurements taken on the ship. We found that in all interpretations of the *in situ* measurements, attention had to be paid to the wind direction relative to the ship, because of local heating from the ship's surface. Although initial examination of the scanning IR radiometer data led to some puzzling results, we now have developed an improved calibration method that uses zenith measurements from the FTIR and accurate sea-air temperature differences are now derived from both the 5-mm and the infra red data. These results have revealed the need for engineering improvements in the IR system.

A method of calibrating the ARM MWR using a liquid N₂ source applied directly to the window (Han et al., 2000) has been developed and used in the Nauru99 campaign. This was used to reconcile island- and ship-based MWR data and proved that the ARCS radiosondes were significantly dry biased.

1.2 Cloud and PBL Remote Sensing Techniques

The application of remote sensors to cloud and PBL dynamical problems is a prime mission of ETL and represents a major portion of our ARM activities. A major thrust of this work is the use of mm-wave radar combined with other remote sensors to deduce cloud microphysical and macrophysical properties. In one approach, we have investigated the use of a ground-based water-vapor differential absorption lidar (DIAL) to measure aerosol properties in the convective marine boundary layer (Wulfmeyer et al. 2000; Feingold et al. 1999). In particular we have focused on retrieval of water vapor density profiles beneath clouds. In the case of well-mixed boundary layers, we have also been able to retrieve RH profiles together with the backscatter profiles. The measured backscatter vs. RH relationship has been compared with a simple aerosol model, and we have shown that the function is very sensitive to variations in the mass fraction of soluble material of an internally mixed aerosol.

A new retrieval method incorporating radar and microwave radiometer data has been developed. The retrieval doesn't depend on the cloud droplet distribution being log normal as shown in the original Frisch method. We examined many different droplet distributions, and found that this is a reasonable assumption over a wide range of droplet sizes. We made comparisons of the radar/radiometer retrievals of liquid water content with those measured concurrently by aircraft in stratus cloud over the SGP CART site during the IOP of April 1997. Results of these comparisons, indicate good agreement for this day. The results were reported in Frisch et al. (2000).

1.3 Profiler/Precipitation Methods

Profilers have already proved useful for diagnosing and classifying precipitating cloud systems in the tropics. Their continuous observations at a number of tropical sites provide a wealth of climatological information that is critical to the objectives of ARM science (Gage et al. 1999; Sekelsky et al. 2000; Williams et al. 2000). The primary focus of the Aeronomy Laboratory (AL) portion of this research effort is to participate in a multiple sensor shipboard campaign conducted in June and July 1999 utilizing the NOAA's new Class I research flagship, R/V RONALD H. BROWN (RHB). The AL was responsible for installing and operating an S band profiler on the RHB during NAURU99. At the same time the AL operated an S-band profiler of similar design on the island of Nauru. Accomplishments to date:

- (1) Deployed the S-band profiler on the RHB for the duration of Nauru99.
- (2) Installed and operated an S-band profiler of similar design on the island of Nauru.
- (3) Collected data from the two S-band profilers and checked the quality of the data.
- (4) Created web text and visualization of profiler images for the Nauru99 S-band profiler data which can now be linked to the NAURU99 web site.
- (5) Created a site where S-band profiler spectral moment data can be retrieved by ARM researchers.
- (6) Collected surface met data and 915 MHz profiler data from Nauru ISS site. We are making this data available to the ARM research community.

2. Field Program Nauru99

The Nauru99 campaign in 1999 expanded on the ship-island theme developed for CSP. A broader suite of shipboard sensors was supported by DOE and loaded onto RHB, in Darwin, Australia, between June 10 and June 15. Onboard were more than 20 scientists from 11 multi-national institutions. After leaving Darwin, RHB steamed for 8 days while taking data and fine-tuning instruments, arriving at NOAA's 2S, 165E TAO buoy on June 23. Here we conducted joint operations for 7 days in a "Large Triangle" configuration with Japanese R/V MIRAI at the 0S, 165E TAO buoy; and with a University of Flinders (Australia) research aircraft - a Cessna 404 - based on Nauru (0.5S, 167E). We noted discrepancies between ship and buoy observations, documented patterns in sea surface temperatures

(SSTs) between platforms, and acquired sufficient data to initialize and validate Single Column Models (SCMs), including high-resolution satellite products and ECMWF gridded analyses.

On July 1 the ships moved into a “Small Triangle” configuration for 4 days, with RHB 22 km southwest of Nauru and MIRAI 40 km north of RHB. The intent was to observe precipitation events propagating through the region with the ships’ weather radars in an ideal dual-Doppler configuration. No appropriate precipitation occurred, so on the last day (July 3) the BROWN steamed to the MIRAI’s position for about 6 hours of direct instrument intercomparisons. On July 4 the MIRAI left the area and RHB began 12 days of intensive intercomparisons with ARCS instruments on Nauru. The ship spent considerable time stationed 1-2 km downwind of the ARCS site or upwind of it on the windward side of the island (approximately 6 km from ARCS). The ship also performed various maneuvers in the vicinity of Nauru to characterize the “island effect,” including circumnavigations and Lagrangian transects of downwind aerosol plumes. The mission ended on July 19.

Some 34 mission-specific datasets were obtained on RHB, including radiosondes; wind profiler; ceilometer; cloud radar; bulk and turbulent fluxes of heat momentum, moisture and CO₂; bulk and surface SSTs; FTIR spectra; S-band precipitation radar; total sky imagery; multi-channel sun photometry; broadband and spectrally-resolved radiative fluxes; multi-channel microwave and IR radiometry; Doppler, DIAL (water vapor), and aerosol lidars; complete surface aerosol characterization; rain gauges; and high-frequency ship motion data. A complete list of measurements made on RHB during Nauru99, status of data processing, and a list of Principal Investigators for the data, can be seen at ETL’s web site <http://www4.etl.noaa.gov/nauru99/>. In addition, ship’s sensors recorded more than 120 oceanic and meteorological parameters continuously throughout the mission.

2.1 Large Triangle

RHB held position within 200 m directly downwind of the TAO buoy at 1.9S, 164.4E (except for June 22-23 when nearly calm conditions required the ship to run several-kilometer-long racetracks around the buoy to properly aspirate instruments on the ship’s bow). The Cessna aircraft overflew the ship and buoy a total of 10 times on 5 days, typically at an altitude of only 30 m along a flight pattern that followed the three legs of the triangle. Low resolution (daily averages) of buoy data were retrieved via NOAA/PMEL operational satellite communications. Higher resolution (two-minute average) data were resident on the buoy, but were not downloaded by ship’s crew because the data were scheduled for downloading within one month, as part of scheduled buoy maintenance. In hindsight, it was a mistake not to download the high resolution buoy data because after the ship’s departure all archived data were lost when sea water got into the buoy’s computer electronics.

Daily-average SSTs compared very well; air temperature and wind speed measured by the buoy were consistently 1 C and 1 m s⁻¹ high with respect to similar sensors on the ship, but some of this difference is explainable by the log-profile behavior of near-surface variables. Also, buoy-measured visible downwelling radiative flux was consistently more than 100 w m⁻² below the same flux measured on the ship by several similar sensors. These results point to a need for standard instrumentation on the TAO buoy servicing ships, and a validation procedure, to better ensure reliable buoy measurements of these important quantities. Comparisons between MIRAI and its TAO buoy were in general more favorable, although air temperature disagreed considerably. Common parameters measured by the Cessna and the ships (e.g., radiative fluxes, skin SST, wind) agreed well, in general, in proximity. The aircraft was invaluable in assessing the spatial variability of parameters along the legs of the triangle.

2.2 Small Triangle

This part of the campaign was not as successful as hoped because very little precipitation occurred in the area, negating planned dual-Doppler radar observations. However, because of closer proximity of the ships to Nauru, the Cessna aircraft was able to quickly circumnavigate the small triangle up to ten times per flight (vs. two times for the large triangle). Aircraft circumnavigations were made at

several altitudes up to 10,000 ft. to help characterize humidity profiles, for comparisons with lidar humidity and aerosol profiles. Side-by-side comparisons of radars, lidars, radiometers, radiosonde, and other systems on the two ships for six hours on July 3 proved useful.

2.3 Island Effects

The RHB spent the first two full days at Nauru positioned 1 km downwind of the ARCS site, to best compare similar measurements made on ship and shore. On July 7 the ship moved to the windward side of the island about 6 km directly upwind of ARCS, to quantify differences in measurements upwind and downwind of ARCS, differences presumably caused by the island itself. We returned to this station on several other occasions for many hours at a time, adjusting the ship's position as needed as wind direction changed. Analysis of these data show no significant difference in cloudiness measured by RHB or ARCS, for either ship position (upwind or downwind). On four other days the ship continuously circumnavigated the island, with each circuit taking about 2 hours. When we analyze these ceilometer data as a function of eight 45-degree-segments around the island (15 min per segment), we do notice a pattern of more cloudiness at ARCS (39.1 %) than is seen simultaneously on the ship when the ship is upwind of ARCS (28.0%). When the ship is directly downwind of ARCS, the cloudiness observed simultaneously by the ship and ARCS (32.9% and 33.8%, respectively) are nearly the same (within statistical uncertainty). These results are preliminary and obviously require more scrutiny.

Another assessment of island effects was made by ETL's shipborne Doppler lidar on days that the ship circumnavigated the island (July 9,10,13,14). On these days the lidar performed RHI scans perpendicular to the ship's motion. Thus, data were obtained nominally from island center radially outward, for 360 degrees around the island. A high gradient in backscattered signals is typically seen at the top of the mixed layer. As the ship circumnavigates, it is thus possible to determine the mixed layer height throughout each scan, and observe changes in mixed layer height as a function of azimuth about island center, as in Fig. 2a and b. These observations show (a) slight lowering of mixed layer height downwind of the island at night (when the surface cools air in contact with it) and (b) marked raising of the mixed layer height downwind during high sun hours (when the surface heats air in contact with it).

Another indication of island effect can be seen in the ship's surface aerosol data set established by PMEL on July 15. On this day the ship made crosswind transects at several downwind distances of the aerosol plume coming from Nauru. It was clear that an island aerosol plume existed because the aerosol count went from low to high to low as the ship moved from undisturbed marine air into the plume and then back into undisturbed marine air. Fig. 3 shows the pattern in coarse mode size distribution as a function of downwind distance.

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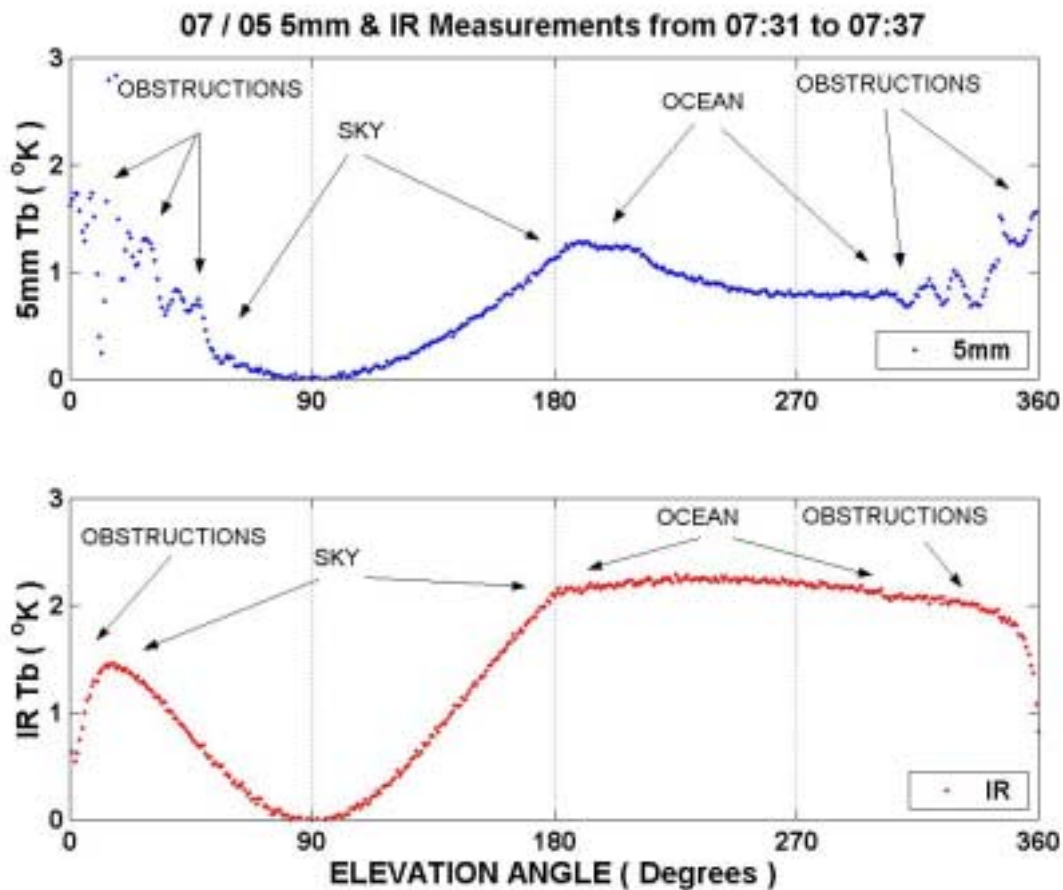
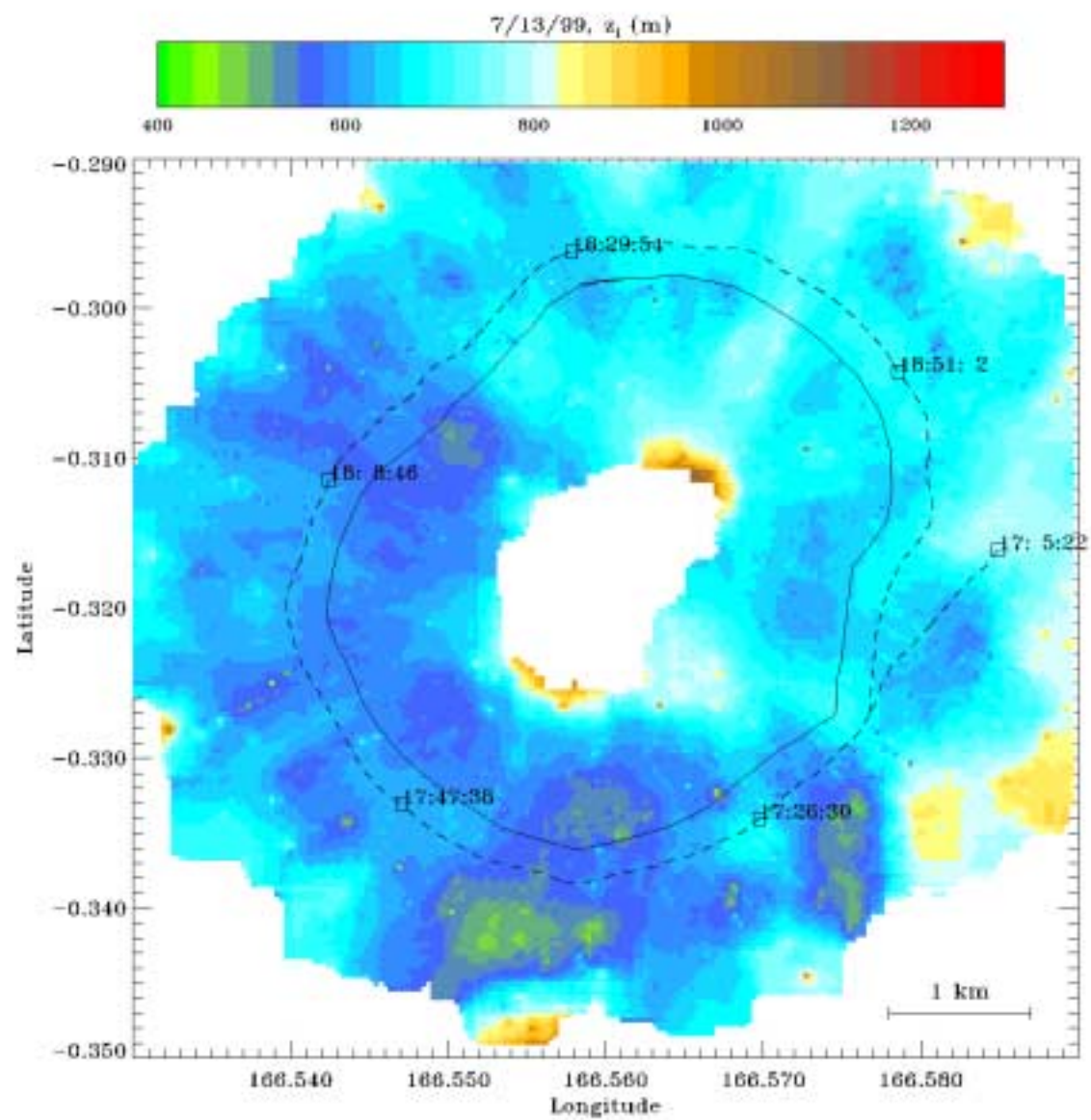
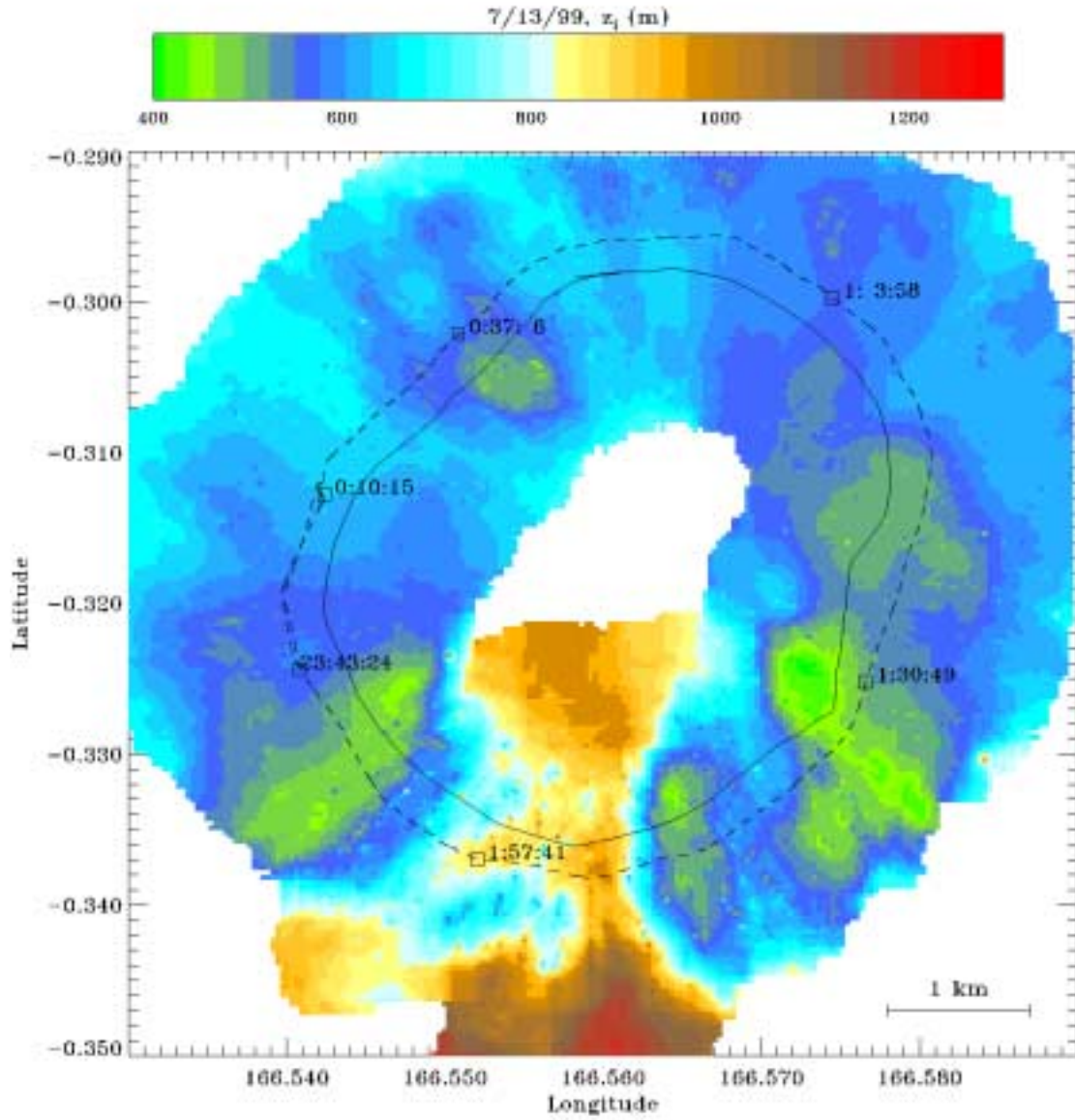


Figure 1. Sample of brightness temperature data from dual scanning IR/microwave radiometers from the Nauru99 experiment: temperature difference (C) from the zenith value versus elevation angle. The upper panel is microwave temperature, the lower is IR temperature. The IR data shows about a 2 C sea-air temperature difference ($T_{270} - T_{90}$). The smaller microwave brightness temperature difference is associated with the sea surface microwave emissivity.



(a)



(b)

Figure 2. Field of boundary layer height derived from Doppler lidar RHI scans made during island circumnavigations on July 13 1999, (a) during local predawn hours and (b) during local early afternoon hours. Ship's track (dotted line) and approximate shoreline (solid line) are indicated.

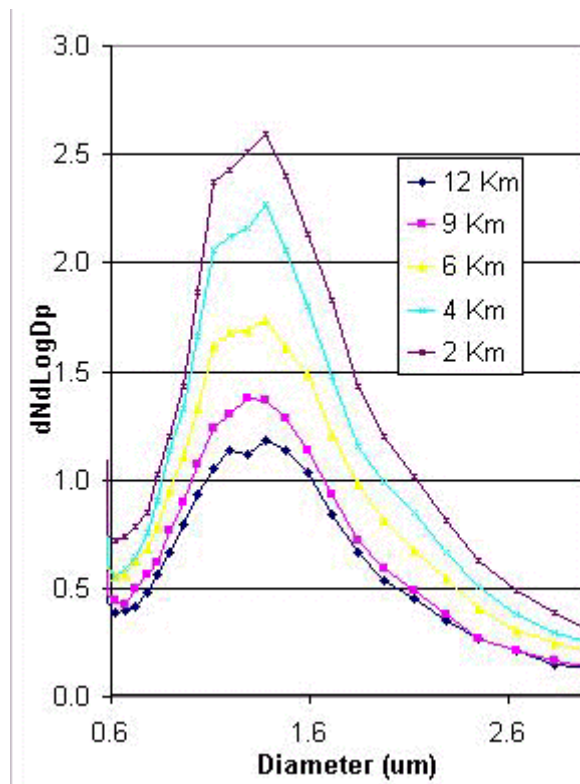


Figure 3. Coarse mode aerosol size spectra within Nauru Island's downwind plume. Data were acquired on July 15, 1999, at successive stations from 12 km to 2 km offshore. Courtesy of Patricia Quinn of NOAA/PMEL.

New/Updated* Publications
July 2000

Refereed Literature

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